Birmingham hip resurfacing

A MINIMUM FOLLOW-UP OF TEN YEARS

R. B. C. Treacy,
C. W. McBryde,
E. Shears,
P. B. Pynsent

From The Royal Orthopaedic Hospital, Birmingham, United Kingdom

We report the survival, radiological and functional outcomes of a single surgeon series of his first 144 consecutive Birmingham hip resurfacing procedures (130 patients) at a minimum of ten years. There were ten revisions during this time. Although no patients were lost to follow-up some did not complete the scoring assessment or undergo radiological assessment at ten years.

The ten-year survival for male patients was 98.0% (95% confidence interval 95.2 to 100). The ten-year survival for the total cohort with aseptic revision as the endpoint was 95.5% (95% confidence interval 91.8 to 99.0) and including revisions for sepsis was 93.5% (95% confidence interval 89.2 to 97.6). The median modified Oxford hip score at ten years was 4.2% (interquartile range 0 to 19) and the median University of California, Los Angeles score was 7.0 (interquartile range 5.0 to 8.0).

This study confirms the midterm reports that metal-on-metal hip resurfacing using the Birmingham Hip provides a durable alternative to total hip replacement, particularly in younger male patients wishing to maintain a high level of function, with low risk of revision for at least ten years.

Hip resurfacing is now regularly used for the treatment of young and active patients with painful primary or secondary arthritis of the hip. Hip resurfacing accounts for 8% of all primary hip replacements and 40% of those performed in patients aged between 55 and 64 years in England and Wales.[1] A survival of 98% at a minimum follow-up of five years has previously been reported,[2] and similar medium-term results have been reported from other institutions.[3-6] The Birmingham Hip (Smith & Nephew, Warwick, United Kingdom) is an as-cast cobalt-chrome molybdenum metal-on-metal device which has remained unchanged in its design and manufacture since its introduction in 1997 other than the introduction of 2 mm increments. Hip resurfacing conserves bone on the femoral side and has been demonstrated to be comparable, with regards to acetabular bone preservation, to uncemented components used in conventional total hip replacement (THR).[7,8] Hip resurfacing also allows patients a high level of function owing in part to the large, more anatomically sized components[9] and also the low rate of wear for this metal-on-metal bearing.[9] The large radius bearing also has the additional benefit of reducing the risk of dislocation.[9] The preceding benefits need to be weighed against the risk of revision, the complications and any long-term adverse effects of a metal-on-metal articulation when compared with conventional THR.

The aim of this study is to report the survival, radiological and functional outcome of a consecutive series of Birmingham hip resurfacing procedures at a minimum of ten year's follow-up.

Patients and Methods

The inclusion criteria for all the hips in this study was that they had been included in the previously reported five-year follow-up series.[2] The cohort consisted of the first consecutive single surgeon (RBCT) series of Birmingham hip resurfacing procedures performed between August 1997 and May 1998. There were 144 procedures (14 bilateral, 11%) performed in 130 patients. The details of the study group are summarised in Table I. The methods of patient selection and operative technique have been previously described.[2] The posterior approach was used for all hips.

Patients were contacted and invited to attend for clinical review at a minimum of ten years following their resurfacing. A form detailing whether the patient had undergone a revision procedure was completed and the

■ R. B. C. Treacy, MD, FRCS (Tr & Orth), Consultant Orthopaedic Surgeon
■ C. W. McBryde, MD, FRCS (Tr & Orth), Orthopaedic Fellow
■ E. Shears, MRCS, Specialist Registrar in Trauma & Orthopaedics
■ P. B. Pynsent, PhD, Director of Research & Teaching Centre Royal Orthopaedic Hospital, Bristol Road South, Northfield, Birmingham B31 2AP, UK.

Correspondence should be sent to Mr C. W. McBryde; e-mail: cwmcbryde@hotmail.com

doi:10.1302/0301-620X.93B1.24134 $2.00

J Bone Joint Surg [Br] 2011;93-B:27-33.
Received 21 December 2009; Accepted after revision 2 August 2010

Table I. Summary of the study group

	Study group (n = 144 hips)
Gender (%)	
Male	107 (*74*)
Female	37 (*26*)
Mean age in years (range)	52 (17 to 76)
Diagnosis (%)	
Osteoarthritis	125 (*87*)
Avascular necrosis	10 (*7*)
Developmental dysplasia	3 (*2*)
Rheumatoid arthritis	2 (*1*)
Other	4 (*3*)
Mean follow-up time in years (range)	10.8 (10.2 to 12.2)
Number of patients with each femoral component size (%)	
42 mm	19 (*13*)
46 mm	22 (*15*)
50 mm	61 (*42*)
54 mm	32 (*22*)
58 mm	2 (*1*)
Not documented	8 (*6*)

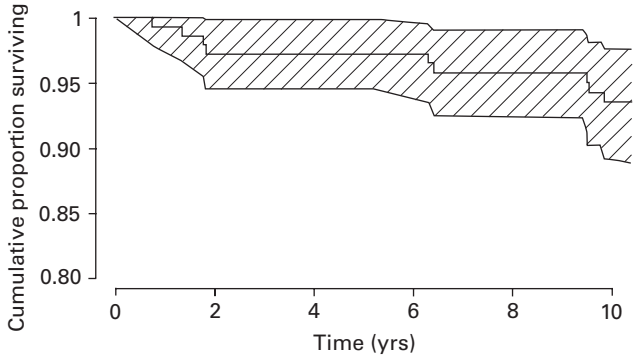

Fig. 1

Kaplan-Meier survival curve for Birmingham hip resurfacing (revision for any reason as the endpoint). The hatched area represents the 95% confidence intervals. The tenth revision at 11.2 years is not included.

patient also completed an Oxford hip score (OHS)[10] but scored according to Pynsent, Adams and Disney,[11] which produces the score as a percentage with 0% as the best result. A University of California, Los Angeles (UCLA) activity score[12,13] was recorded, and a standardised anteroposterior (AP) radiograph of the pelvis was taken. Patients who were unable to attend were contacted either by telephone or by post and completed a questionnaire regarding any revision surgery. These patients also completed the modified OHS, a UCLA activity score and were asked to attend a local hospital for a pelvic radiograph which was forwarded for analysis. If a revision procedure had been performed, details of the location of the surgery, the reasons for revision and the findings at surgery were obtained from the treating surgeon or hospital. All deaths occurring in the study period were analysed to establish if there was any relationship to the hip resurfacing procedure. Each radiograph was analysed by an independent researcher who was blinded to the other outcomes. All available radiographs were assessed in a digital format using the open source software OsiriX (OsiriX Foundation, Geneva, Switzerland). The inclination angle of the acetabular component and femoral component to femoral shaft angle were measured. This latter angle was defined as the obtuse angle between a line down the centre of the proximal femoral canal and a line down the centre of the femoral component. The femoral component was considered to have radiological evidence of loosening if there was a radiolucent line > 2 mm in any one of the three zones described by Amstutz et al.[14] Acetabular loosening was recorded if there was a radiolucent line > 2 mm in two or more zones described by DeLee and Charnley.[15] Any osteolysis around the femoral or acetabular component was recorded. Thinning of the femoral neck was considered to be present if there was a greater than 10% reduction in the minimum width of the femoral neck adjacent to the margin of the femoral component on the ten-year AP radiograph when compared with the same dimension on the initial post-operative radiograph. This was calibrated by measurement of the edge of the femoral component. If the femoral neck had evidence of a surgically induced inferior or superior notch > 1 mm on the ten-year radiograph then this was also recorded. No patients were lost to follow-up, with each patient confirming whether they had undergone a revision procedure.

Statistical analysis. Survival calculations and Cox-proportional hazard modelling was performed using the R program.[16] Revision of either the femoral or acetabular component, or both, was used as the endpoint in this study. The Cox-proportional hazards model was used to examine the relationships between the different survival distributions of each covariate entered into the model.[17] The baseline hazard for the group and the relative proportional hazards for each of the covariates were extracted. Covariates that were not significantly influential were systematically removed from the model to identify those that had the greatest influence on survival.[18] Functional scores were assessed using the median and interquartile range (IQR). For the modified OHS, only those questionnaires with more than ten of the 12 questions answered were considered valid and the percentage derived from the questions answered was taken as the final value.[11] The level of significance was set at 95% ($p < 0.05$) and confidence intervals (CI) are also at the 95% level. The Peto method was used to produce the confidence limits of the Kaplan-Meier survival calculations.[16]

Results

The ten-year survival with revision for any reason as the endpoint is 93.5% (CI 89.2 to 97.6) (Fig. 1; Table II).

Table II. Life table for Birmingham hip resurfacing (revision for any reason)

Year	Number at risk	Number of revisions*	Probability of revision (%)	Cumulative survival (%)	95% confidence interval
0	144	0	*0*	*100*	100 to 100
1	143	1	*0.007*	*99.3*	98.0 to 100
2	140	3	*0.021*	*97.2*	94.5 to 99.9
3	139	0	*0*	*97.2*	94.5 to 99.9
4	139	0	*0*	*97.2*	94.5 to 99.9
5	139	0	*0*	97.2	94.5 to 99.9
6	138	0	*0*	*97.2*	94.5 to 99.9
7	135	2	*0.015*	*95.8*	92.5 to 99.1
8	134	0	*0*	*95.8*	92.5 to 99.1
9	131	0	*0*	*95.8*	92.5 to 97.6
10	117	3	*0.026*	*93.5*	89.2 to 97.6

* the tenth revision at 11.2 years is not included

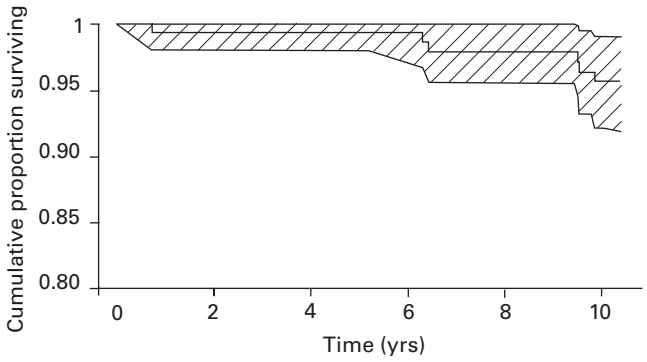

Fig. 2

Kaplan-Meier survival curve for Birmingham hip resurfacing (revision for any reason as the endpoint excluding infection). The hatched area represents the 95% confidence intervals.

There were ten revisions during the study period of which three were for deep infection. Survival at ten years with aseptic revision as the endpoint was 95.5% (CI 91.8 to 99.0) (Fig. 2). The mean follow-up was 10.9 years (10.2 to 12.2). There was one fracture of the femoral neck, which appeared to be avascular in origin, at nine months after operation, and this has been previously described.[2] There were three revisions for avascular necrosis (AVN) of the femoral head (occurring at 6.4, 9.5 and 9.9 years) of which two were in patients with a previous history of AVN. The revision at 9.5 years was in a patient with bilateral idiopathic AVN of the femoral head who had bilateral resurfacings, the left of which is included in the study (surgery on the right side was performed later than May 1998). Following the left-sided resurfacing the patient had improvement in his symptoms and following his right-sided hip resurfacing returned to manual work. However, he continued to suffer intermittent and variable pain from the left hip. Investigation did not reveal a cause for the persistent symptoms which were not considered severe enough to warrant revision. At eight years post-surgery hip aspiration showed no growth, inflammatory markers were within normal limits but radiographs suggested that there might be progression of AVN with slight movement of the femoral component into varus. At 9.5 years his symptoms warranted revision but at surgery the femoral and acetabular components were found to be well-fixed. Revision of the femoral component to an uncemented metal-on-metal THR was performed with retention of the acetabular component. The patient was asymptomatic following the revision.

The case requiring revision at 9.9 years for progression of AVN was the youngest patient in the cohort. She developed idiopathic AVN at 15 years of age and underwent an unsuccessful attempt at arthrodesis of the hip in the same year. Two years later she remained symptomatic and hip resurfacing was performed with some difficulty. She remained asymptomatic for seven years during which she had two healthy children. Progressive pain then developed and loosening of the femoral component was apparent on plain radiographs. At revision there was minimal staining of the tissues due to metal debris but extensive AVN of the femoral head. Although the acetabular component was well fixed, it was felt to be excessively anteverted so her hip was converted to a ceramic-on-ceramic THR. A further revision was in a male patient with a diagnosis of osteoarthritis (Fig. 3). Initial and follow-up radiographs were satisfactory and he was asymptomatic until the sixth year post-surgery, at which time he developed symptoms and the radiograph demonstrated that the femoral component had tilted into varus. He underwent a revision at 6.4 years for AVN of the femoral head but the acetabular component remained well-fixed. The femoral component was revised to a cemented stemmed metal-on-metal hip replacement with retention of the acetabular component. One revision was performed at another institution at 6.3 years in a woman with a history of developmental dysplasia of the hip. Prior to her initial resurfacing at 42 years of age she had undergone a number of procedures including a Salter acetabular osteotomy and a femoral derotation osteotomy as a child. At hip resurfacing, the anatomy was very abnormal requiring a dysplasia acetabular component with two screws to address acetabular deficiency. At six years post-

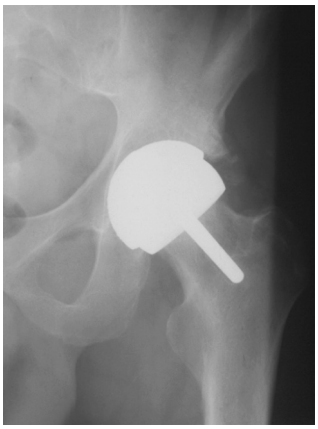

Fig. 3a

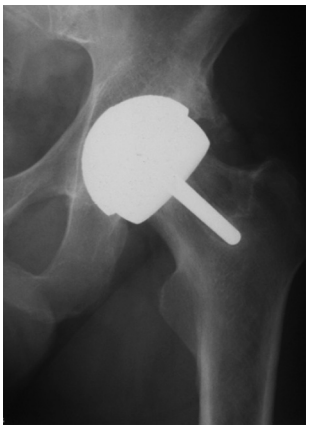

Fig. 3b

Fig. 3c

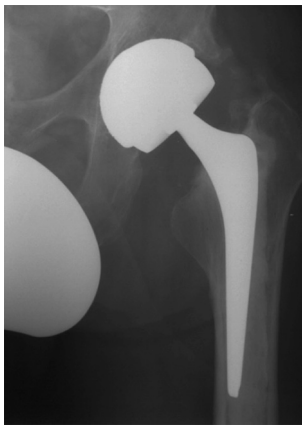

Fig. 3d

Radiological series of a patient showing the femoral component moving into an increasingly varus position at a) early post-operatively, b) three years post-operatively, c) six years post-operatively with pain and d) post-revision. The patient was symptom-free until six years post-operatively. At revision the femoral head demonstrated signs of avascular necrosis.

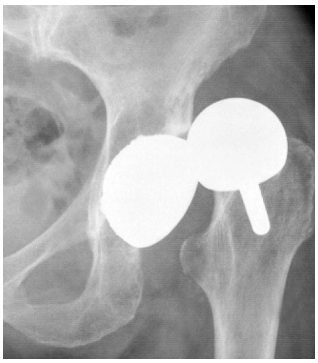

Fig. 4

A radiograph showing the hip of a female patient who suffered recurrent dislocations. Revision surgery at 9.5 years found a large amount of peri-prosthetic fluid. The acetabular component was in both excessive anteversion and excessive inclination.

resurfacing she underwent revision of the femoral component for presumed loosening at another institution, but no further information is available. In one patient, aged 73 years at the time of operation, the acetabular component moved into a position of excessive inclination in the early post-operative period. Although initially asymptomatic the patient subsequently developed recurrent dislocation and underwent revision at nine years (Fig. 4). At revision to a THR at another institution, she was found to have much peri-prosthetic fluid with the acetabular component being in both excessive anteversion and inclination. Following revision there were further dislocations requiring another revision to a 'captive design' acetabular component. The tenth revision was in a patient who had been asymptomatic with satisfactory radiographs until ten years when she incurred a displaced intracapsular fracture to the neck of the femur after a fall. At operation to convert the hip to a metal-on-metal THR with retention of the acetabular component, the resurfacing component was found to be still firmly secured.

Cox's proportional hazard analysis for survival with revision for any reason as the endpoint identified that head size and gender were significantly associated with revision ($p = 0.006$, $p = 0.0002$). The ten-year Kaplan-Meier survival with revision for any reason as the endpoint for the male patients was 98.0% (CI 95.2 to 100) and for those with a femoral component size ≥ 50 mm was 97.7% (CI 94.6 to 100). Age was not significantly associated with revision ($p = 0.22$). Systematic analysis identified the covariates of gender and femoral component size to provide the best description of the data ($p < 0.05$ for the combined model). The Cox model including the co-variates of gender and head size identified that there was a 1.14 times increase in the risk of revision per year with every decrease in femoral component size (4 mm) and a 5.78 times increased yearly risk of revision if the patient was female. A number of checks of the final Cox model were performed to ensure that the fitted regression model adequately described the data. These included examination for violation of the assumption of proportional hazards and for influential data, and checks for non-linearity in the relationship between the log hazard and the covariates. All of these enquiries confirmed that the Cox regression model adequately described the data.[18] There were nine patients (ten hips) who died during the study period. None of the deaths were related to the hip resurfacing and no deaths occurred in the first two post-operative years. The survival for the study group with death as the endpoint is 94.9% (CI 91.1 to 98.6) at ten years.

Of the original 130 patients (144 hips), nine patients (ten hips) died, and ten hips were revised (in ten patients). This left 111 patients (124 hips) available for review, of whom 98 (88.3%) completed a modified OHS at a minimum of ten

years. The median modified OHS was 4.2% (IQR 0 to 19). There was one patient with an unusually high score of 77% at ten years, who had a primary diagnosis of AVN of the femoral head. The radiograph demonstrated no evidence of loosening but some progressive thinning of the femoral neck. The patient did not want a revision operation.

Of the 111 patients (124 hips), 90 (81.1%) completed a UCLA activity score. The median score was 7.0 (IQR 5.0 to 8.0). Of these 111 patients (124 hips) radiographs were only available for 77 (62%), as 45 patients (47 hips) had declined to have radiographs taken. None of the available radiographs demonstrated any evidence of loosening of either the femoral or acetabular components. There were no cases which demonstrated either femoral or acetabular osteolysis. The mean acetabular inclination angle was 49° (CI 49 to 50) and the mean component to femoral shaft angle was 141° (CI 140 to 142). Five hips had an inferior notch and four a superior notch of the femoral neck. None of these had failed and the appearance of each notch had not changed. Radiographs of four hips demonstrated greater than 10% thinning of the femoral neck compared with the initial post-operative radiograph. In one of these hips the thinning was progressive with an underlying diagnosis of AVN.

Discussion

Hip resurfacing prior to 1997 had been largely unsuccessful.[19-22] Between 2005 and 2006 there were reports of early success of what came to be known as third-generation hip resurfacing, which includes the Birmingham hip.[2,23] Hip resurfacing has been reported to allow a high level of activity, reduce the risk of dislocation and preserve femoral bone stock for any subsequent revision.[9] Hip simulator studies demonstrated that the metal-on-metal bearing had minimal wear.[24,25] There are few papers which report the results of resurfacing beyond five years. [6,26,27]

The survival in this single surgeon consecutive series of his first 144 cases was 93.5% (95% CI 89.2 to 97.6) and the survival with aseptic revision as the endpoint was 95.5% (95% CI 91.8 to 99.0) at ten years. Of the cases not revised one is symptomatic, as represented by a high modified OHS, although no revision is planned. Of the other surviving prostheses 76 hips (70 patients) which underwent radiological examination showed no evidence of loosening or progressive thinning of the neck. According to the modified OHS the survivors are asymptomatic (median score of 4.2%, IQR 0 to 19, at ten years) and are continuing at a high level of function (UCLA score, median 7.0 (IQR 5.0 to 8.0)). At the time when these patients underwent hip resurfacing the sensitivity of the position of the acetabular component to high angles of inclination and anteversion was not fully appreciated. It has subsequently become clear that excessive acetabular inclination or excessive acetabular version alone or in combination leads to increased production of wear debris from which local soft-tissue reactions and aseptic lymphocytic associated lesions can arise.[28-30] It is suspected that this may have been a factor in the patient revised for recurrent dislocation in this series, although no histology was available to confirm this. The accurate preparation of the femoral head, cementing technique and subsequent positioning of the femoral component also have important implications for the survival of the prosthesis.[31-33] This appears to be of particular importance in relation to the risk of fracture of the neck of the femur.[31]

Thinning of the neck of the femur was found in four of the 77 (5.2%) radiographs available at ten years. Of those, only one appears to have progressed during the study period. Progressive thinning of the neck raises concerns of impending failure and this patient with a primary diagnosis of AVN is also symptomatic. Radiological evidence of progressive thinning of the neck was seen in one of the hips revised due to AVN but was not seen in the two revisions for fracture of the femoral neck. The three remaining hips with thinning of the neck demonstrated no progression after the first post-operative year and are asymptomatic at ten years. There are no other features of concern on the radiographs. We highlighted a limitation of our study, in that ten-year radiographs were only available for 62% of those who have not been revised at ten years and thus thinning of the neck may be more frequent than this study indicates. Nevertheless, in those hips which had thinning of the neck it seemed to occur only in the first year then stabilise, and only rarely was found to progress.

These findings are in agreement with the findings of an independent study of hip resurfacing in Australia.[34]

Contact was made with all patients for the purposes of survival analysis and thus all revisions in this cohort are accounted for. It is disappointing that these patients did not all complete assessment forms at ten years, which also limits our study. However, during telephone contact with these patients in which it was confirmed that no revision had been performed, they reported that they were asymptomatic. We acknowledge that even when standard AP radiological assessment was performed this may not identify patients with soft-tissue reactions to metal debris and more sophisticated imaging would be more informative in this respect.[35]

All surgery was performed by one of the designing surgeons. It is recognised that their results cannot always be reproduced when the surgery is performed by others. This series does however include part of this surgeon's learning experience with this implant which is recognised to be more technically demanding to implant than conventional hip replacement, with the consequence that Birmingham hips implanted during the initial period may have less favourable results.[36,37]

It has been reported that larger head size may be a better predictor of improved survival than male gender alone.[38] At present the national joint registries do not report the results of hip resurfacing at ten years and are weighted to the short-term outcome, owing to the larger numbers being performed in more recent years. It is hoped that the national joint registries will provide further information to help guide patient selection in the future.

Patient selection is crucial to the success of hip resurfacing.[36,39,40] When this non-randomised cohort was selected during 1997 the indications were less stringent than currently accepted. Hip resurfacing was then offered to active, symptomatic patients, in whom it was deemed possible to perform a resurfacing and who had expressly wished to have a high level of function following the operation. The majority of failures in this series have occurred in female patients. Eight failures in 37 female patients initially appears alarmingly high when compared with conventional THR. In mitigation, the sample size of women is extremely small. In the female group there were three infections, and a further failure was in a patient over the age of 70 years at the time of the procedure. A further female revision was in a teenager who had an extremely difficult hip to resurface, having had many previous operations including an arthrodesis which failed. A final female patient suffered a basal fracture of the femoral neck at 11 years after operation following significant trauma. She had up to that point been asymptomatic with a high level of function. Despite this it is essential that follow-up of a larger cohort of female patients is performed before firm conclusions about the suitability of hip resurfacing in women can be made.

It has now become clear that the best results of the Birmingham hip resurfacing procedure are achieved in male patients with a primary diagnosis of osteoarthritis. In this cohort male patients demonstrated a prosthetic survival of 98.0% (95% CI 95.2 to 100) and a high level of function. This study provides evidence that the metal-on-metal Birmingham hip resurfacing offers an acceptable alternative to conventional THR in male patients requiring a high level of function with a low risk of revision for at least ten years.

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We would like to acknowledge the support of the McMinn Scholarship from the British Hip Society.

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